STRATEGY RESEARCH PROJECT

IMPLICATIONS OF HIGH-RESOLUTION, COMMERCIAL SPACE IMAGERY FOR NATIONAL SECURITY AND HOMELAND DEFENSE

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ABSTRACT

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This paper examines the current and near term, high-resolution, commercial space imaging (CSI) capabilities and the potential impact on the United States, particularly as related to threat intelligence collection, targeting, and policy challenges. This rapidly growing segment of technology is surveyed, followed by a near term capabilities projection. The resulting, general threats to the United States are then developed. Examples of the types of intelligence available to an adversary are explored. Finally, potential courses of action to prepare for and mitigate these threats are discussed.

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INTRODUCTION

While we grapple with the combination of direct attacks on the United States and the swirl of technological change all around us, we continue to miss a growing number of technologically based threats. Key of these is the recent and growing direct access from space that potential adversaries have to observe and analyze essentially any part of the United States or U.S. foreign operation they wish. Access to high-resolution space imagery was, until recently, limited to a small number of well-heeled states with the industrial and technical capacity to develop, launch, and operate satellites. This is no longer the case.

This paper examines the technological and policy trends of high resolution, commercial space imaging, extrapolates current capability into the near future (2010), defines the general threat posed by the capability, and concludes with proposals to mitigate the threat. The genie of near real time, high-resolution observation of the earth's surface is out of the bottle. It cannot be put back. The focus here will be on commercial, publicly accessible, and licensed space imaging systems and their application in ways that pose threats to the United States. Not discussed are systems such as low-resolution weather satellite systems, and applications such as land use planning, forestry, and hydrology. Also omitted are government controlled space imaging systems that do not release products to the public.

Growth in the capability of commercial space imaging (CSI) systems will pose new threats and challenges by the year 2010. Some forms of these are emerging today as CSI capabilities surpass 1-meter resolution and image availability reaches near real time. A growing number of nations are launching commercial imaging satellites and selling the imagery on the open market. By 2010, the ability of any group with the financial assets to discern objects one foot in size from space, and to detect a wide variety of other activity using radar and other imaging sensors, represents a significant military and political capability. Threats and challenges are not limited to the direct threat posed by observability of activities. They are more importantly manifest in information based challenges to government policy, diplomacy and decision-making. The most threatening, least recognized, and most likely manifestation of this threat is as a component of information operations directed at national policy formulation and execution.

COMMERICAL SPACE IMAGING DESERT STORM/1992

Much has changed in the intervening years since Desert Storm. In 1992, commercially available capability was limited to a small number of space imaging systems, most of them operated by governments. Resolution of publicly accessible systems was typically in the 10-meter or greater range.[1] In 1992 only two commercial panchromatic (visible light), gray scale imaging systems were flying: France's SPOT 1 and 3. The United States and Japan were flying commercial infrared satellites in 1992 that operated with resolutions between 18 meters and 1.1 kilometers. The United States, Japan, and CIS also flew radar-imaging satellites with resolutions between 15 and 100 meters.[2]

Ten-meter resolution does not provide sufficient image detail to be of use by news organizations and is of limited use to potential adversaries. Military uses of imagery in the 10-meter or greater range are limited to exploitation and identification of large facilities such as logistics facilities, ports, and assembly areas and to terrain and environmental applications. Identification or counting of ground vehicles and aircraft is generally impossible at this resolution.

While not possible to build order of battle with this imagery, it was used as an air mission-planning tool by the United States. The combination of commercial imagery with DOD digital terrain data made it possible to produce mission rehearsal graphics for U.S. aircrews.[3] This capability has been available on the open market for a number of years, but it offers little utility in support of terrorist or small-scale military operations. It is more applicable to geospatial and terrain analysis than it is to developing detailed target intelligence.

COMMERICAL SPACE IMAGING 2002

The CSI market has changed dramatically since 1992 with rapid growth in the number and capability of systems and the number or countries in the market. Identification of all the players in the market is a complex task unto itself, with published listings of operating companies varying from source to source. For example, a NASA listing of commercial systems does not list any systems flown by an international consortium dominated by Israel called ImageSat International.[4] Yet, this group is significant in that it not only sells imagery, but it also leases exclusive satellite access, to include full tasking authority over the sensor. Customers can essentially rent an imaging satellite. From the company's web site:

> The Satellite Operating Partner service provides a customer with exclusive tasking rights for confidential *reception of images at his ground station* (emphasis added) and the use of one or more dedicated ImageSat International satellites over a specific geographical area. ISI provides dedicated systems that are

operated as an "end-to-end system" by SOP customers, from imaging mission planning, satellite tasking and satellite imagery collection and processing in real-time.

SOP customers are equipped, within six months, with all the hardware and software that is required to operate the satellite in real-time.

Satellite Operating Partner Ground Receiving Stations (SOPs) communicate and task EROS satellites directly whenever they are within a 2,000-2,400 km radius of the station. SOPs send their fully confidential Imaging Plan to the satellites as they enter a station's communication range and receive images as the plan is executed in real time. SOP use of individual satellites is guaranteed by ISI and may not be pre-empted by other customers or by ISI.[5]

Prior to 1992, only the United Sates, France, and Japan were persistently in the commercial space imaging market. Russia was also in the market using older film return systems that were not as commercially viable as data linked systems because of delayed image availability.[6] Russia's marketing emphasis today remains on mapping and terrain products. India, Canada, Israel, and South Korea are also marketing imagery today with Australia on the threshold.[7]

Systems flown today carry a wide variety of sensors and have widely varying capabilities. The most common sensors are in the various infrared bands, to include multi-band or multi-spectral (MSI) systems. Panchromatic (PAN), essentially black and white photography, is the next most common, followed by synthetic aperture radar (SAR) imaging systems. SAR systems differ significantly from other systems in that they are not passive. They illuminate the target with radar energy, and therefore, the images are not literal and they require more specialized interpretation than IR and PAN images.

Space Imaging Incorporated and their IKONOS satellite represent the present state of the art for commercial PAN imagery. This satellite, operated under license from the U.S. Government, produces imagery at 1.0-meter resolution. It has demonstrated the capability to produce 0.8-meter resolution images under optimal conditions.[8] ImageSat International also sells products with an advertised resolution of 1-meter, but in some listings, it will have a 0.82-meter capability in 2002.[9] Today, there are approximately 14 PAN imaging systems flying, 8 of them with 10-meter or better resolution. By 2005, 3 more systems will be launched, two by France and one by Japan, all with 5-meter or better resolution.[10]

There are approximately 39 infrared (IR) systems flying today. Many of them are used for weather, and mapping and therefore, have correspondingly low resolutions. Twelve of these systems have a resolution of 50 meters or better. Countries other than the U.S., or U.S. foreign

partnerships, fly ten of these. The best resolution available is 4-meters in the near infrared (close to visible light) and is a sensor on the Ikonos satellite flown by Space Imaging. Resolutions are significantly worse at longer wavelengths on all systems with the best thermal IR resolution of 30-meters achieved by the U.S. Landsat systems. The best foreign thermal IR system is an 80-meter resolution sensor on a joint Chinese-Brazilian system called CBERS. Countries operating or collaborating in operating IR satellites are France, the European Space Agency (ESA), Russia and the Commonwealth of Independent States (CIS), China, Brazil and Japan.[11]

The current commercial market for synthetic aperture radar (SAR) is much smaller but is notable in the absence of the United States. However, the United States flew test systems on the space shuttle in the early 1990s.[12] There are currently five SAR systems flying operated by the European Space Agency (ESA), Canada, and a joint U.S./Japanese partnership. Three of these are sub-50 meter resolution systems.[13] Commercial space-based SAR is a relatively new capability in which a significant user market has yet to develop.

COMMERCIAL SPACE IMAGING 2010

PANCHROMATIC

As in much of the technological growth around the world, and especially in computing, analysts might assume trends in image resolution improvement similar to that in automation as defined by Moore's Law.[14] This is not the case. Government licensing requirements, market forces of low demand and over capacity, and simple diminishing returns for investment are all decelerating resolution improvements. PAN imagery resolution improvements are unlikely to dominate future growth in CSI. The market will instead broaden to embrace more specialized applications through expansion of sensor spectrum capabilities into infrared (IR), multi-spectral (MS or MSI), and imaging radars. However, PAN imagery is the most photo-like, and is likely to have the most popular appeal in the news and consumer markets. IR and SAR imagery, conversely, are much less literal and require specialized training to extract usable, and more importantly, correct information

The relatively long-term operational history and higher number of PAN satellites provides more numerical data for analysis than sensors in other bands. Plotting best available, announced near term PAN CSI resolution in three-year time blocks on an arithmetic scale, and superimposing a best-fit numerical plot yields Figure 1. The trend is a rapid decline in the rate of change of resolution improvement or a deceleration in improvement. The relatively minor improvement in resolution in recent history yields a projection line so flat that it is of little value.

Figure 2 rescales the plot to a logarithmic axis making the right end of the curve more visible. It is important to recognize that projections plotted in this manner necessarily have large errors at the tails. Projecting forward produces a PAN resolution of approximately 0.12-meters (5 inches) in 2007, and 0.105 meters (4 inches) in 2010. This shows little improvement after 2007, and in fact, small changes in the projected curve produce large errors to the right on the line.

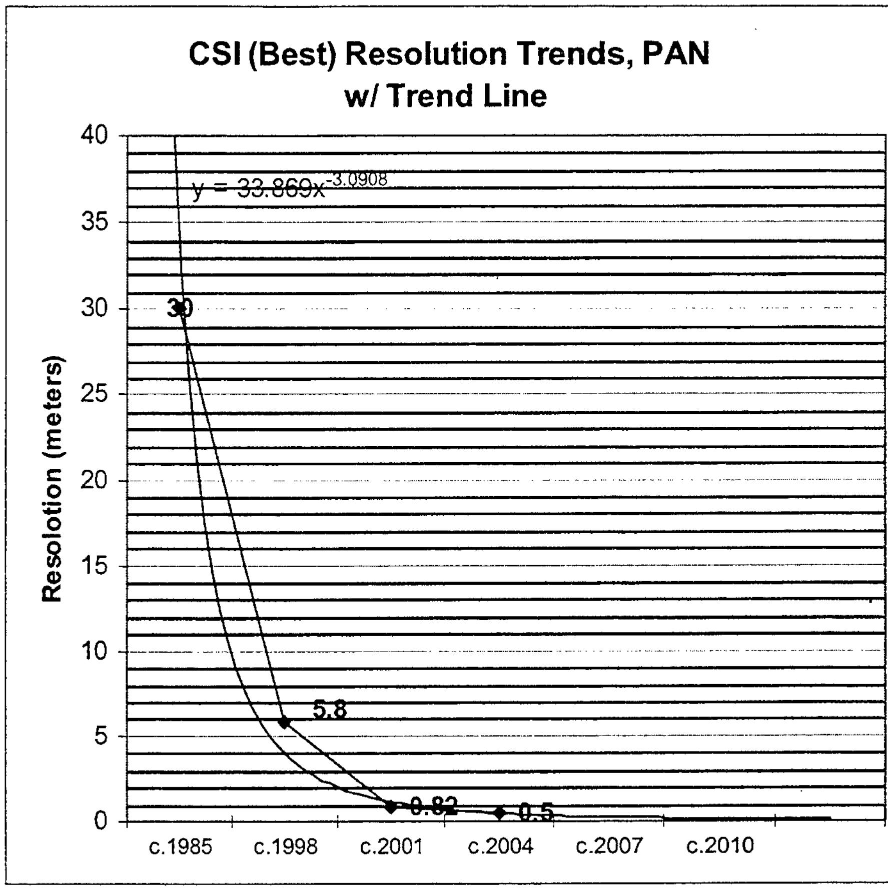

FIGURE 1

Extrapolation beyond 2010 is arguably of little value, as new limiting factors will emerge to distort the trend line. For example, there is an approximate inverse relationship between resolution and area covered in an image. High resolution yields a small area of coverage analogous to the difference between a standard and telephoto lens on a camera. Therefore, the higher the resolution of the image, the more demanding the act of pointing becomes. At an indeterminate point in the future, pointing accuracy challenges or other technological obstacles are likely to make resolution increases extremely costly or technically unreachable. Similar limitations are likely to emerge from atmospheric distortion or other physical limitations.

Non-technological limitations in the form of market forces however, already appear to be limiting resolution gains, at least for the foreseeable future. One-meter imagery entered the public market amidst much fanfare, but the expected market for this space imagery has not emerged.[15] The number of competitors exacerbates the lack of a market with Orbital Sciences, ORBIMAGE, DigitalGlobe, and SPOT comprising the big four in the market. In the next 5 years, other foreign competitors will enter the market. Canada, India, Japan, and Russia all plan to

launch and operate new imaging satellites.[16] It is reasonable to predict that the CSI industry will undergo a shake out similar to that of the auto industry post WWII, and the personal computer industry in the 1990s. Some of the companies operating today will either succumb to competition, or merge with stronger competitors, leaving a few stronger companies à la the auto industry of today. An additional assumption is that as demand for higher (and more costly) resolution increases, the number of customers making the demand decreases, potentially making sub 1-meter imagery a specialty item, limited to governments, militaries, and possibly corporate consortiums, and news outlets. An indicator of what the future might like is the low-resolution CSI (remote sensing) markets for weather, cartographic, and hydrological imagery. A steady diet of this imagery is now part of daily life, but it remains a specialized product. It supports markets ranging from the Weather Channel and the local nightly weather forecast, to government support of public cartographic and health requirements to land use planning across the country, yet it is not a consumer item. These markets are well developed and more stable than the much younger 1-meter PAN CSI market. With these observations and assumptions in mind then, it is reasonable that the high-resolution end of the CSI market will be similarly market limited, and not technologically limited. Therefore, it is likely that CSI PAN imagery will, at best, achieve a resolution in the vicinity of one-foot (0.33-meter) by 2010. (Figure 3).

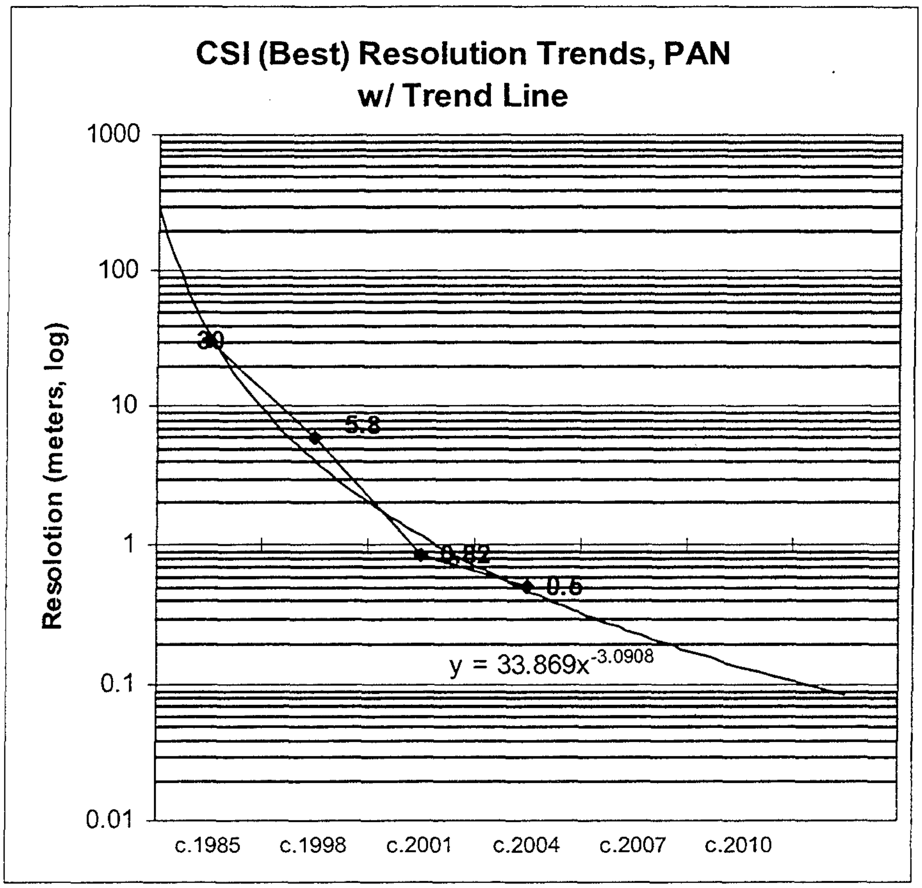

FIGURE 2

A trend just as significant as resolution improvement of PAN imagery is the growth into IR, non-visible light imaging and synthetic aperture radar (SAR)[17]. Examination of this area of CSI

reveals too few systems to establish predictive resolution trends, but does reveal gross capabilities for the future.

INFRARED

Imagery using sensors that operate outside the visible light band hold the promise of obtaining information that is not visible to the naked eye. With the public and press focus on low-resolution numbers possible with PAN imagery, IR, to include multi-band sensors, and active illumination and imaging of targets by radar appear to have been relatively ignored in the press. Announced satellite launches do not alter the market much except to add Australia to the list of nations flying IR satellites. Resolutions are not likely to improve significantly through 2010 over current capabilities in the thermal IR band. Best resolution in near IR is not likely to improve either, although there are more satellites forecast to achieve resolutions of around 10-meters. There are presently ten sub-50 meter IR systems announced for launch before 2005. Four of these are foreign.[18] Significant commercial resolution improvement by 2010 is unlikely given the generally flat trend, particularly in the thermal IR band. Interpretability gains, however, are likely through better multi-band sensors leading to enhancement in the ability to detect objects and characteristics not otherwise visible. Subjectively, the best resolutions through 2010 are likely to be 4-meters in the near IR band and 20-meters in the thermal IR band.

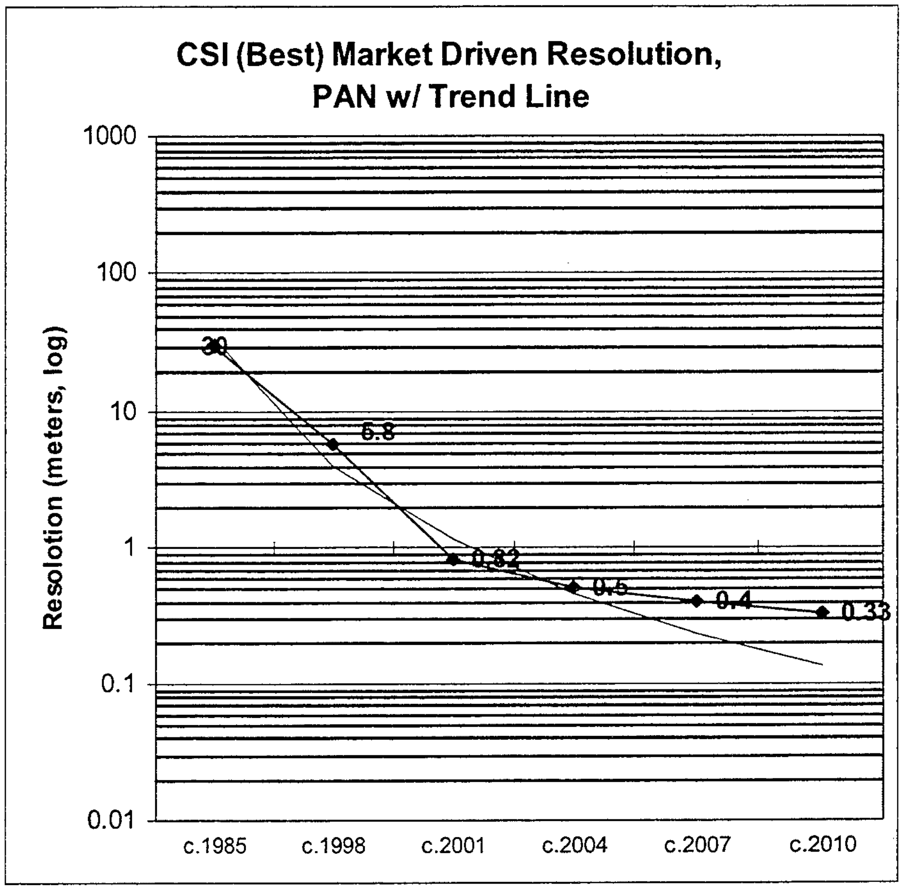

FIGURE 3

SYNTHETIC APERTURE RADAR (SAR)

Expansion of the space born SAR market may have more impact, although resolutions will lag that of PAN. SAR imagery is the least literal of the extant imaging capabilities but it has the peculiar capability to highlight human features and to penetrate some types of materials such as weather, vegetation, and dry sand. A very notable and public example is the detection of an entire buried, and previously unknown river valley in Libya.[19] The radar was flown on Space Shuttle Endeavour STS-59 as a joint U.S./German/Italian project in 1994.[20] Of note is that there are no announced plans to launch a U.S. commercial SAR system. Even with the U.S. absent, the market is likely to expand with the addition of the Russia and Canada. Through 2005, eight future systems have been announced, five of them from the Russia. Canada has announced the best resolution at 3-meters, with other systems announced in the 5-meter range.[21]

Extrapolation of SAR resolution is not supportable because of the lack of history, but it is possible to predict operational advances in the near future based upon present test-bed systems flown on aircraft. The publicly acknowledged state of the art for aircraft based SAR is 0.3 meters (1 foot). Sandia National Laboratories has published a number of examples of one-meter SAR images and 0.3-meter SAR movies collected from their systems flown on conventional aircraft.[22] These images appear literal, but are not because of the path followed by radar reflections. The time taken for a radar pulse to return to the sensor rather than reflected light, as in the human eye, determines the location of an object on a radar image. Therefore, objects that reflect multiple bounces of the radar beam will appear further away from the sensor than their actual location. Doppler effects produced by moving objects also distort the location of objects.[23] Therefore, specialized interpretation is required. Consequently, it is unlikely that a significant commercial market will emerge. It is likely that commercial uses of SAR will remain specialized. Further discussion assumes a 1-meter, space-based SAR resolution in 2010.

An additional and key component is timeliness. Most companies do not publicly advertise capabilities in terms of time from imaging to customer delivery. U.S. Government licensing, in fact, places timeliness restrictions in the license contract to U.S. companies. For example, the U.S. Government restricts Space Imaging from delivering an image to a customer within 24 hours of image collection.[24] Near real-time will be used as the standard here for image deliver in 2010, however, since the Israeli, ImageSat International advertises this capability today.[25]

Table 1 summarizes the predicted resolution and delivery capabilities in 2010. Multi-band IR capabilities are assumed to lie between that of near and thermal IR.

APPLICATION 2010

Sensor Type	Max. Resolution	Timeliness
PAN	0.33m (1 foot)	Real Time
Near IR	4m	Real Time
Thermal IR	30m	Real Time
SAR	1m (3 feet)	Real Time

TABLE 1: CSI CAPABILITES 2010

CSI at the resolutions in Table 1 eliminates many of the current and traditional uses of CSI such as hydrology, water and land use planning, and weather as suitable applications of high-resolution sensors. These activities will remain the province of existing low-resolution systems where large fields of view are required. However, higher resolutions, and spectral bandwidth increases and combinations, open up new means of collection, create new observables, and produce new threats.

Traditional military applications- surveillance, observation, target development and planning support, readily come to mind. The addition of a space observation capability gives an opponent ready access to previously denied areas at resolutions approaching that available from a highflying aircraft or terrestrial observation from a distance of a few miles. Looking at PAN imagery only at 0.3-meter resolution, an imagery analyst would be able to identify some types of radio and radar equipment as components of larger systems– air defense radars for example. They could also identify types of supply in a dump, and precisely identify vehicles and small aircraft, to include remotely piloted aircraft. Detailed description of troop formations in the field, airfields, ports, missile sites and ships, is possible, as is technical analysis of larger facilities, such as ports, bridges, rail facilities, and roads.[26] In short, anyone with the financial resources can produce detailed order of battle on military units and can monitor unit level activity and operations.

The observables above are in agreement with the U.S. Intelligence Community's National Image Interpretability Rating Scale (NIIRS).[27] On this scale, 0.3-meters falls in the range of NIIRS 7.[28] NIIRS is further broken out by the type of sensor, but for the purposes of this discussion, the differences are not particularly relevant except in instances where a sensor type permits detection or identification of a feature not observable on higher resolution PAN imagery. Commonly cited examples are disturbed earth on IR, camouflage and dead vegetation on multi-spectral imagery, and non-metallic decoys on radar imagery.

Publicly available information on NIIRS scales focus almost exclusively on military equipment. However, it is straightforward to transfer to non-military targets with similar size, dispersion, and activity. For example, given the level of detail discernable in ground military activity, it would also be possible to identify characteristic truck activity associated with refueling

of a nuclear power plant (or other similar industrial activity) that indicates a window of vulnerability for terrorist attack. In this instance, there is remote observability of a denied area, and the opportunity to produce a dirty bomb without moving nuclear material to the target– it is already there.

Application of other sensor types, even though at the lower resolutions, can also yield significant intelligence. Staying with the nuclear power plant example above, the lack of a heat plume from cooling towers or in cooling water discharge observed with a thermal IR sensor, even at 30m resolution, would indicate an inoperative plant.[29] This again is intelligence of potential value to a terrorist group. At the state level, similar application of thermal data on aluminum production plants, for example, may aide a state in price or treaty negotiations for bauxite ore. The potential applications, both beneficial and threatening, are wide ranging.

Going a step further, gross security measures at a wide variety of installations and facilities are observable at 0.3-meter resolution. While space based observation at this resolution would clearly lack sufficient detail to plan an attack on a facility, it would provide detail on physical barriers such as fence lines, berms, approaches, and in some cases, external lighting and guard facilities. Sufficient information to rule out a target or to aide planning for direct observation is available for purchase on the commercial market.

All of this theoretical observability, however, is subject to limitations on the utility of the information that are not immediately obvious. As analysts in most fields know, a single observation of an issue or problem frequently reveals very little. Things like trends, changes, abnormalities, and ultimately meaningful prediction, are absent or not possible with a single look. This is the case whether analyzing stocks, or producing target intelligence for an attack. Long-term observation is required to build an accurate picture of a target, whether it is from the ground, or from space. Therefore, except in specific cases, intelligence application of CSI remains extremely expensive considering target revisit requirements. The requirement for revisit may explain the high end, high dollar marketing by ImageSat International of turnkey ground station systems with complete imaging control.[30] Therefore, gaining detailed, actionable intelligence from CSI will primarily remain in the province of states and the world's largest multinational corporations. The need to revisit targets, however, does produce an emerging threat in the realm of information operations.

Use of CSI to shape and develop, or even initiate public debate, is emerging as a fact.[31] The use, and possibly deliberate miss-use, of CSI is rapidly progressing from simple error in news reporting to direct use of CSI to launch a public policy debate. An example of the former is the case of TV news organizations reporting that two reactors had melted down at Chernobyl

in 1986 based upon a single satellite image with a solar reflection on a reactor building.[32] An example of the latter is the March 2000 use of CSI of a Pakistani nuclear facility to challenge the U.S. Government assertion that Pakistan had given up its nuclear program.[33] While history has shown the assertions of the challenge to be correct, it remains unknown what affect there was on U.S. policy execution and U.S.-Pakistani relations. The very real potential exists to precipitate crisis with CSI through ill-timed public policy challenges based upon application of incomplete information or the advancement of deliberate political agendas.

The "amateur imagery analyst" further exacerbates the problem.[34] The amateurish and erroneous interpretation of a single image, as happened in the Chernobyl case above, could under other circumstances, cause any number of crises. Application of poor technical expertise is not hard to find. GlobalSecurity.org images of the Pentagon before and after the 11 September 2001 attack are an example. Here text descriptions identify the imagery as "one-meter resolution" imagery. This is not necessarily the case as one-meter is the best attainable. Space images are frequently at less than optimum resolution because of variation in the satellites altitude and atmospheric affects. Annotation of the images is also confusing and misleading. The images are annotated with a scale in the form, "1 pixel =~ x meter" with the resolution apparently improving beyond the capability of the sensor as the image is cropped, or by "zooming into" the image. In a post 9/11 image of the Pentagon, a heavily cropped section of a Space Imaging Ikonos image of the Pentagon is shown and is labeled "Scale 1 pixel=~0.25 meter."[35] This appears to be a statement of the resolution of the image, when it is probably a description of the pixel size of the JPEG computer image. The Ikonos operating license limits resolution to 1-meter; magnification cannot improve upon that. This lack of technical accuracy sets the stage for interpretive confusion and confrontation between interest groups, the press, and the U.S. Government. The incorrect or distorted use of CSI can split the focus of government policy-makers and implementers between the original problem, and a new public challenge to an issue.

> "...a looming concern for the IC *(intelligence community)* should be whether or not a representative from a special interest group armed with a limited number of high-resolution satellite images obtained from a commercial venture can initiate significant debate over foreign policy or national security issues and force the IC to respond... ...sensitive imagery analysis techniques and data derived from other intelligence disciplines ... are at risk if the USG is drawn into public debate with special interest groups that use high-resolution satellite imagery to support agendas that differ from U.S. foreign policy and national security positions."[36]

Imagery has a component of false credibility because "it" is there for all to see, despite the fact that the conclusions may simply be wrong. The average person, seeing the examples

above, would tend to accept that what they are looking at is as claimed. Going beyond error, intent to deceive will to turn poor analysis into an offensive information operations (IO) weapon. Policy and decisions become vulnerable to attack through deliberate miss-interpretation or alteration of the imagery. Policy makers may find it difficult to maintain the initiative in this situation. The likely ubiquitous nature of high bandwidth, instantaneous communications around the world by 2010 will further enhance the viability of his form of attack.

ACTORS 2010

Any list of possible actors capable of effectively exploiting CSI to threaten the United States is unlikely to change much by 2010. States without the resources or technical capability to launch and operate imaging satellites will probably remain the largest users of CSI. Other users are likely to be large corporations, terrorist groups, and political and environmental groups with policy agendas to advance.

Well-organized and funded terrorist groups are likely to make occasional use of CSI, but not to produce detailed technical and target intelligence. The revisit and database requirements are likely to keep effective use of CSI beyond the financial reach of these groups. Ground observation and surveillance of targets will remain the preferred and most cost effective means of collection. Terrorist groups are likely to make use of CSI for initial target selection and post attack observation. Post attack imagery would prove particularly valuable as propaganda and motivational tools for internal use.

Political action and environmental groups are also likely users of CSI by 2010. Some of these groups are extremely well funded. Greenpeace, for example, received donations totaling approximately €126 million ($110 million) in 1999 and Amnesty International operated on a budget of approximately $25 million in the same year.[37] The tools available to advance these groups causes can easily include CSI.

The United States is vulnerable to the threats posed by use of CSI by terrorist and politically motivated groups. Most of these threats serve to wrest the political and informational initiative away from the government as opposed to supporting direct, physical attack of a target. SCI's use or misuse will tend to accelerate decision cycles and processes, and consequently increase the risk of miss-step or error in decision-making. It is likely that in the near future we will observe a demonstrable instance of CSI forcing a national policy or operational decision or of precipitating a crisis. This event, even if unintended, will signal the beginning of the use of CSI as a tool of information operations. This threshold will be all the more significant if it is the result of a deliberate use of CSI as a debate-shaping instrument.

As the war on terrorism progresses, more opportunities will emerge for policy shaping uses of CSI. For example, it is somewhat surprising that groups opposed to U.S. actions in detaining prisoners at Guantanamo Bay, Cuba have not used CSI to press the debate on prisoner of war status for the detainees or to make the case of mistreatment. There are two possible explanations. The first is that the use of imagery would hurt the group's agenda, or second, that this is symptomatic of the previously identified soft market for CSI and a perceived lack of benefit for the cost.

SOLUTIONS AND RECOMMENDATIONS

A wide variety of responses are available to the United States. The least desirable is to fail to recognize the challenge and to do nothing. The most desirable then is to plan and rehearse in advance. If circumstance drives, and policy bounds the response to a threat, then policy is the variable available to shape possible responses. Response to specific threats or challenges can be one or any combination of law, physical action, and procedural changes. Proactive policy development requires advance consideration of all of these areas.

LEGAL

For legal restrictions to be effective there must be either an international governing body, or the Untied States must dominate the high-resolution market to such and extent that the it could implement effective controls.[38] Serious movement toward the former does not appear to exist. In the latter case, the expansion in the number of foreign CSI systems, the growing number of countries in the market, and the U.S.'s apparent abandonment of the SAR market all indicate that the opportunity to dominate the market is lost. A market shakeout is likely in the near future. This will eliminate many of the companies presently in or entering the CSI market. The survivors will likely be those with home government backing, and despite a significantly changed competitive landscape, the U.S. will not emerge as the sole force in the market.

States with the financial means, technical skill, and will to stay in the market will remain. Russia today is a prototypical example of a state that will stay in the commercial market as a subsidy to its internal intelligence requirements. The same is true of the direction taken by the Unites States.[39] Given a lack of U.S. market domination and the number of emerging international actors in the market, it is unlikely U.S. legal and international treaty restrictions as a counter to CSI derived threats will be effective.[40]

Change to legal restrictions, at least in the U.S., is necessary. Prohibited target lists and customer black lists are also justifiable, as is government access to customer and imaging records in accordance with existing laws for other types of corporate records. This is an area

also ripe for international treaty and agreement to establish reciprocal procedures for imaging control and access to records. While probably impossible to deny an adversary all remote access (short of destroying an imaging system), there is benefit in making it difficult to circumvent controls.

OFFENSIVE

Offensive action to counter a threat falls squarely into the much larger area of general space access and warfare. In the instance of national emergency and warfare, direct attack on a system, either the space or terrestrial segments, is a viable consideration in the larger context of military operations and space access.[41] The probability of reaching this threshold of action is remote and has little or no applicability to the more probably circumstances of use of CSI in support of terrorist activity or as an IO weapon.

DEFENSIVE

Defensive strategies generally focus on the traditional tactics of denial and deception an on engineering design. The first concern is in protecting military information, particularly movements and dispositions of units. Early in deployments is more critical than later, particularly when there is a command requirement for surprise. Re-implementation of cold war practices of issuing routine satellite over flight warning messages, and implementing local procedures and orders to reduce or eliminate observability during threat windows will provide protection for most small-scale military activity. Protection of large-scale military activity such as the mobilization or deployment of an Army division, or the unscheduled sortie of Naval surface combatants is much more difficult to hide, and therefore requires external support.

A supporting, and often ignored protective tactic is installation and facility design. Everything from motor pools, deployment staging areas, military aircraft parking and naval berthing should be examined in the design (or retrofit) stage for addition of protective measures to reduce observability. There is a clear cost/benefit conflict, but retrofit of features to facilities to deny observability of areas exhibiting high potential for exposing damaging military information is necessary. Military construction programs should include a threat assessment and anti-satellite observability as a design criterion.

The same recommendations apply to industrial design. Returning to the nuclear power plant thread above, design of plants, especially observable security measures should include consideration of remote space observation. Additional examples include non-public areas of airports, ports, refineries and other key industrial and technology plants. Existing military and selected industrial facilities should be subject to threat assessments to identify existing

vulnerabilities. Emphasis on observable staging and deployment areas, and likely terrorist targets in areas closed to public access would focus the effort. Observability analysis must also consider all sensors, not just PAN imagery. For example, heat from an active reactor in a power plant could mask the cold status of another within the same complex.

ADAPTING

Adapting is a catchall to encompass a key recommendation of building awareness and shaping perceptions about CSI threats. Adapting is not a term to engender hand wringing, but one of change. Technological change in society happens without a grand plan. If change is to happen with a purpose and objective, then plans are required. The most likely challenges from CSI will be in the policy arena. These policy challenges will have some general characteristics:

-Speed of information flow,

-Short decision cycles,

-Nearly instantaneous, world-wide visibility,

-A government bureaucracy initially less agile than the challenger.

Use of CSI to press an agenda or force policy decisions may have already occurred. Further challenges are likely in the future. The characteristics of a challenge to policy are likely to cause the government to lose the initiative temporarily. Regulation as a tool to control this challenge is not possible given the international nature of the market. Excessive U.S. regulation would simply drive the market offshore. What remains is acceptance of this new environment and a need to develop new and agile policy, and operating methods.

The key to improving the agility of a government response to a policy challenge is advance planning. It is not enough for imagery analysts, or even senior military leadership to recognize the problem: recognition and planning must be interagency. Analysis and exercise of policy options in advance of these types of challenges will improve agility in dealing with them. Having general guidelines in place for dealing with CSI driven policy challenges will significantly shorten the government's response time and correspondingly improve the credibility of the response. There are a number of potential policy options, to include silence, release of intelligence data, and establishment of Intelligence Community (IC) partnerships with non-governmental organizations.[42] Other earlier proposed options are promotion of the free flow of information, negotiated restraints, and direct countermeasures (combination of offensive and defensive).[43]

Silence simply capitalizes on the existing shortfalls, further damaging credibility. Release of intelligence data will usually be a poor option because repeated compromise of sources and methods will rapidly erode the IC's capabilities and relevance. In particularly serous examples, however, this may be a legitimate and feasible option. U.S. display in the United Nations of imagery of Russian missile sites in Cuba is a good historical example.[44] Development of general guidelines for release of intelligence, with streamlined and practiced procedures is essential. Established partnerships and trusted relationships will speed the development of responses when public disclosure of intelligence to refute challenge is not justified.

Exercise and testing of proposed responses will build confidence and further improve government agility. Just as the military at all levels practices interaction with the press, so should there be practice in dealing with technological and IO based challenges to operations and policy. Incorporation of CSI derived challenges into existing exercises, particularly in the Department of Defense should be a priority under the greater umbrella of exercising IO.

CONCLUSION

The proliferation of high-resolution commercial space imaging systems presents a wide variety of threats and challenges. The ability of anyone or any group with the financial assets to obtain space imagery capable of discerning objects down to one foot in size and to detect a wide variety of other activity using radar and multi-spectral imaging represents a significant military and political capability. The most threatening, least recognized, and most likely of these is the use of imagery as a component of information operations directed at policy formulation and execution. By re-instituting old protective procedures and practices, and by integrating consideration of space observability into operational planning and facility design we can reduce the threats posed by direct observability. Responding to this change in the operational landscape requires action now. The most important is recognition of the trends in space imaging capabilities, the use of the products, and of the impact on operations and policy execution. We can adapt to and mitigate the changed environment once we have recognized these changes. The most critical task is to develop action plans for policy challenges that will facilitate government agility in dealing with a challenge based upon conclusions drawn from CSI. By 2010 it will be necessary for us operate with the realization that what we do is observable, and that what is observed may either be interpreted incorrectly, or may be deliberately misrepresented.

Word Count: 6322

ENDNOTES

[1] Imaging resolution is a linear measure (distance). The given value is the minimum distance or separation required between objects to resolve them as two distinct objects in the image. In the vernacular, it is frequently the smallest sized object discernable on an image. The distinction may seem trivial, but can be significant. For example, given an image of 1-meter resolution, a row of concrete traffic barriers that are 3 meters in length would appear as a continuous object if they had a 1-foot/0.3-meter gap between the barriers. At a 1-foot or less resolution they would appear to be distinct objects of 3m length. Ground sampling distance (GSD) is also used as a measure of resolution and in electro-optical systems may be expressed as different values in each axis. The difference between GSD and resolution are trivial for the purposes of this paper.

For a visual comparison of space imagery in the range of 1 meter to 30 meters, see http://geo.arc.nasa.gov/sge/health/sensor/rescomp/rescomp1_30.html; Internet; Accessed 10 February 2002.

[2] "Past Sensor Systems," 7 May 1999; available from http://geo.arc.nasa.gov/sge/health/sensor/pastsensor.html; Internet; accessed 13 February 2002.

[3] "U.S. pilots take tactical advantage with visualization of Desert Storm targets," available from http://www.spot.com/home/appli/surveys/pilot/pilot.htm; Internet; accessed 10 February 2002.

[4] "Current and Future Sensor Systems," November 2001; available from http://geo.arc.nasa.gov/sge/health/sensor/cfsensor.html; internet; accessed 13 February 2002.

[5] "Satellite Operating Partner (SOP)," available from http://www.imagesatintl.com/1024/index.shtml, and navigating the following links: "Click Here to Enter; Services," and following the "Next..." link until arriving at http://www.imagesatintl.com/1024/services/sop.html; Internet; accessed 13 February 2002. Navigation path verified 4 April 2002.

[6] "Currrent and Future Sensor Systems," and "Status of Selected Current & Future Commercial Remote Sensing Satellites by Launch Date," available from http://www.tec.army.mil/tio/ StatusbyLaunchDate.htm; internet; accessed 10 February 2002. Russia has periodically entered the market with the Resurs-01 satellite in 1994 and1988 carrying multi-spectral sensors and the KVR-1000 film return PAN system in 1998.

Russia markets imagery products through Aerial Images, Inc., in Raleigh, North Carolina company (http://www.spin-2.com/) and claims one and two meter resolution capability.

[7] "Current and Future Sensor Systems."

[8] "Eye Spy," The Economist, v. 361, no. 8247, Nov 10-16, 2001: 74.

[9] "Status of Selected Current and Future Commercial Remote Sensing Satellites."

[10] "Current and Future Sensor Systems."

[11] "Past Sensor Systems."

[12] "PRESS KIT -- Space Radar Laboratory 2," available from http://www.jpl.nasa.gov/radar/sircxsar/sirc-pkt.html; internet; accessed 10 February 2002.

[13] "Current and Future Sensor Systems."

[14] Moore's Law: After Gordon Moore (1965): Moore's Law originally stated that the number of transistors on a microprocessor would double approximately every 12 months (now accepted as every 18 months). References for this phenomenon are nearly ubiquitous. For example see: http://www.zdnet.com/pcmag/features/future/moore01.html; Internet; accessed 10 February 2002. This curve fits other technological advances quite well. Examples include CPU processing power and speed, super computer computational power, and commercial, consumer level bandwidth. An initial assumption in this project was that Moore's Law would apply to the resolution of commercially available satellite imagery. This is not the case, and in fact, CSI resolution improvement illustrates that factors other than the technological ability can limit technological advancement.

[15] Winston Beauchamp, Director of Futures Office, Innovision Directorate, National Imagery and Mapping Agency (NIMA), telephonic interview by author, 22 January 2002.

[16] "Current and Future Sensor Systems."

[17] For an introductory description of how synthetic aperture radar (SAR) works, see "The Archives @ JPL: Synthetic Aperture Radar," available from http:// southport.jpl.nasa.gov/, and follow the "What is imaging radar, and how does it work?" and the "educational areas" links; internet; accessed 10 February 2002. Examples of one and three meter resolution SAR: "Sandia National Laboratories: Ku-Band Synthetic aperture Radar Imagery," available from http://www.sandia.gov/radar/imageryku.html; internet; accessed 10 February 2002.

[18] "Past Sensor Systems."

[19] "Wadi Kufra, Libya," available from http://www.jpl.nasa.gov/radar/sircxsar/wadik.html; internet; accessed 10 February 2002.

[20] "PRESS KIT -- Space Radar Laboratory 2."

[21] "Current and Future Sensor Systems."

[22] "Ku-Band Synthetic aperture Radar Imagery," and "Sandia National Laboratories: Synthetic aperture Radar Movie Gallery," available at http://www.sandia.gov/radar/movies.html; internet; accessed 10 February 2002.

[23] Author's professional experience and background as an imagery intelligence officer. A more detailed description is at "Sandia National Laboratories: What is Synthetic Aperture Radar?" available at http://www.sandia.gov/radar/whatis.html; internet; accessed 10 February 2002, and at http://southport.jpl.nasa.gov/; internet; and following the "Science and Applications; Imaging Radar Reports; What is Imaging Radar?" links. Accessed 10 February 2002.

[24] Vernon Loeb, "U.S. Is Relaxing rules on Sale of Satellite Photos: After a Year-Long Policy Review, Far Greater Detail Being Allowed," Washington Post" (Final Edition, 16

December 2000): A.3 [database on-line]; available from UMI ProQuest; accessed 4 December 2001.

[25] "Satellite Operating Partner (SOP)."

[26] Ann M. Florini, "The Opening Skies: Third-Party Imaging Satellites and U.S. Security," International Security, (Fall 1988): v. 13:2, p.98.

[27] Federation of American Scientists (FAS), "National Image Interpretability Rating Scales," available from http://www.fas.org/irp/imint/niirs.htm; internet, accessed 15 February 2002. Multiple links are available from this page to more detailed descriptions of NIIRS and its development.

[28] Ibid, and "Civil NIIRS Reference Guide, Appendix III: History of NIIRS," available from http://www.fas.org/irp/imint/niirs_c/app3.htm; internet; accessed 15 February 2002, p. 37-39.

[29] Hui Zhang and Frank N. von Hippel, The Application of Commercial Observation Satellite Imagery for the Verification of Declared and Undeclared Plutonium Production Reactors (18 October 1999), available in .pdf electronic file format from http://www.princeton.edu/~globsec/pdf/reactor.pdf; internet; accessed 15 February 2000, p. 10-14, 17, 22-32. This electronic document includes an MSI image example of Chernobyl before and after the 1986 accident clearly showing the cooling pond heat plume (p.24), examples of Savannah River Plant heat plumes (p.27), and a side-by-side comparison of PAN and thermal IR images of a Canadian nuclear plant on p.30. Note: on 7 April 2002, this document was no longer available at the Princeton web site, apparently because it is now for sale at http://www.princeton.edu/~cees/reports.shtml; internet, listed as "Report No. 319."

[30] "Satellite Operating Partner (SOP)."

[31] Senator Daniel Akaka, "Security and Commercial Satellite Imagery," Congressional Record – Senate, 146 Cong Rec S3908 11 May 2000.

[32] Florini, p. 108, and Dino A. Brugioni, "Satellite Images on TV: The Camera Can Lie," The Washington Post, 14 December 1986, sec. H1, p. H1.

[33] Senator Akaka.

[34] Edwin K. Lear, "The 'Amateur' Imagery Analyst– A New Challenge for Intelligence: Public Access to Commercial High-Resolution Satellite Imagery," attachment to electronic mail message to the author, <Larry@portouw.com>, 3 December 2001.

[35] "The Pentagon," available from http://www.globalsecurity.org/military/facility/pentagon-ikonos.htm; internet; accessed 24 February 2002. Select each displayed image and note the resolution annotations to make comparisons.

[36] Lear, 1-2.

[37] Frances Pinter, "Chapter 8: Funding Global Civil Society Organizations," Global Civil Society Yearbook, (The Centre for the Study of Global Governance), available from

http://www.lse.ac.uk/Depts/global/Yearbook/Fundingchap.htm, internet, accessed 17 February 2002.

[38] Dana J. Johnson, Scott Pace, and C. Bryan Gabbard, Space: Emerging options for National Power, (Santa Monica, CA: Rand, National Defense Research Institiute, 1998), 32.

[39] Beauchamp.

[40] Johnson, 33.

[41] Johnson, 40-41.

[42] Lear, 26-28.

[43] Florini, 118.

[44] Examples of Cuban Missile Crisis imagery are available from http://library.thinkquest.org/11046/recon/photos.html and http://www.gwu.edu/~nsarchiv/nsa/cuba_mis_cri/photos.html; internet; accessed 24 February 2002.

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